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This study examined whether students who left biomedical fields of study during college did so primarily because they became disenchanted with those fields or because they felt attracted to alternative fields of study. We identified 1,193 students intending to pursue biomedical fields of study early in college, collected data about their beliefs and performance throughout college, and interviewed them near graduation about their future plans. Descriptively, we examined the topics students discussed as affecting their attrition decisions. Predictive research aims were to determine how academic performance, interest, and demographic factors predicted students' likelihood of overall attrition and likelihood of reporting distinct reasons for attrition. Among the 192 students who left biomedical fields, 62.5% described leaving only in terms of feeling disenchanted, whereas 37.4% expressed that they left at least in part due to feeling attracted toward nonbiomedical fields. Most students who left biomedical fields expressed changing plans for reasons related to interest; this was especially prevalent among students who reported leaving due to attraction toward nonbiomedical fields. Predictive analyses showed that interest in biology and grades at the end of an introductory biology course predicted the likelihood of overall attrition and likelihood of leaving due to feeling disenchantment, whereas underrepresented ethnic minority status predicted these outcomes positively. Interest and course grades also predicted the likelihood of students leaving due to feeling attraction toward other fields, but interest was a stronger predictor relative to grades. Results highlight distinct types of attrition that may have implications for policies to promote STEM retention.

Educational Impact and Implications Statement

This study shows that students reflect on their attrition from biomedical fields of study during college in distinct ways. Results of interviews demonstrated that many students reported leaving biomedical fields because they felt disenchanted with them; however, 37.4% of students reported leaving biomedical fields at least in part due to feeling attracted to positive features of nonbiomedical fields. Both biology grades and interest affected students' likelihood of leaving biomedical fields; these two factors predicted leaving due to disenchantment equally strongly, whereas interest played a stronger

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role compared to grades in predicting whether students left due to attraction toward other fields. This study points to the importance of considering positive factors associated with alternative fields that shape students' attrition instead of focusing only on negative factors that make students feel disenchanted with biomedical fields. It also reinforces prior research demonstrating the need to support students' interest in and perceived competence in biology as a path to ensure continued participation in biomedical fields.

Keywords: expectancy-value theory, interest, STEM attrition, biomedical fields, college

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Across a variety of careers, there is an increasing need for individuals to be proficient in science, technology, engineering, and mathematics (STEM) skills, such as data analysis and analytical reasoning (Association of American Colleges and Universities, 2013; National Science Board, 2018). However, 30% to 50% of students who enter college intending to complete a degree in STEM do not achieve this goal and thus lose opportunities to develop STEM skills (Chen, 2013; National Science Board, 2018). Furthermore, individuals who are African American, Hispanic/Latina/o, and/or Native American (i.e., underrepresented racial/ethnic minority (URM) students) are even more likely to leave STEM majors or career paths compared to their peers (e.g., Beasley & Fischer, 2012; Chang, Sharkness, Hurtado, & Newman, 2014; Shaw & Barbuti, 2010). To alter these trends, it is critical for educators to understand why students leave STEM fields of study during college. The present study examines students' explanations for leaving one important category of STEM fields: the biological and medical sciences (hereafter referred to as *biomedical fields*).

A large body of research has examined what factors or personal characteristics predict attrition from STEM fields, including biomedical fields, identifying several key predictors such as poor performance in introductory STEM courses (Chen, 2013) and low interest or value for STEM coursework (Seymour & Hewitt, 1997). Most of this work has focused on how negative experiences of or perceptions in STEM (e.g., difficulty, social costs) might cause students to lose interest, feel less confident, or become dissatisfied with STEM; we refer to such perceptions and/or experiences in this article as students feeling *disenchantment* with STEM fields. This work is critically important, particularly with respect to developing educational supports that encourage students to stay in STEM. However, not all students who leave STEM fields do so because they feel negatively about STEM. Rather, some students leave because of positive experiences in other majors or career paths that make them feel *attraction* toward non-STEM fields (Seymour & Hewitt, 1997; Strenta, Elliott, Adair, Matier, & Scott, 1994; Thoman, Arizaga, Smith, Story, & Soncuya, 2014). Distinguishing between students who leave due to feelings of disenchantment versus attraction is important for two reasons. First, it provides a more nuanced understanding of students' experiences. These two types of attrition are likely to carry very different meanings for students. In particular, if students feel that they left because they were attracted to non-STEM fields, they may think about leaving more positively than students who feel that they left due to disenchantment with STEM. Second, this distinction has implications for strategies to promote STEM degree attainment. Understanding factors that make students feel disenchanted with STEM fields may help inform what retention and support strategies can best prevent students from perceiving these fields negatively. In contrast, understanding what factors attract students toward non-STEM fields can help educators learn why students might perceive non-STEM fields as appealing (e.g., other fields seem more interesting, students think they can be more successful in other fields). It is an open question whether students who perceive their attrition positively should be encouraged to remain in STEM majors or career paths, but if educators do want to retain these students, they might be able to use students' insights to reframe STEM fields in a way that will make these fields seem similarly appealing.

To date, little research has explored whether students who abandon STEM fields in postsecondary education feel more strongly that they left due to disenchantment with STEM fields of study as opposed to attraction toward non-STEM fields. Thus, it is not clear how frequently students report leaving STEM fields due to disenchantment as opposed to attraction, what students' experiences of attraction to non-STEM fields look like, or what factors predict students reporting disenchantment or attraction as their primary reason for leaving STEM fields. The present study aimed to address these questions with respect to biomedical fields.

Factors That Affect STEM Attrition

The present study builds upon a large body of prior research that has explored students' pursuit of STEM fields at different points in their educational trajectories. Many factors influence students' motivation and persistence, including some that prevent students from ever wanting to pursue a STEM field of study in college in the first place (e.g., low performance or interest in math and science during secondary school; Heilbronner, 2011; Maltese & Tai, 2011). We focus in this study on factors that influence attrition after students have entered college with a desire to pursue a STEM major or career path, because this is a critical attrition point with respect to students leaving STEM educational trajectories (e.g., Chen, 2013). Extant work on this topic has examined both the psychological processes associated with college STEM attrition as well as demographic differences in attrition rates.

Psychological Processes

One of the most prominent theoretical models used to understand and explain students' academic choices such as choosing a biomedical major or career path is Eccles and colleagues' (1983) expectancy-value theory of motivation. This theory posits that

there are two primary psychological variables that influence academic choices: (a) students' expectations that they will be successful in a given academic field (in this case, a biomedical field), and (b) the extent to which they value that field, in terms of how useful, interesting, and important it is (see Wigfield, Tonks, & Klauda, 2016, for a review). Expectancy-value theory assumes that students' experiences in STEM fields (including performance in STEM courses and interactions with peers, faculty, and STEM professionals) affect their choices to pursue a STEM major indirectly by affecting their expectancies (or other competence-related beliefs) and task values (Eccles, 2007, 2009; Wang & Degol, 2014). According to this perspective, students are most likely to leave STEM fields because of low confidence and/or low value for their intended majors or career paths, and these motivational processes are influenced by students' achievement and other experiences in their college courses.

Research exploring attrition from STEM fields during college provides support for the expectancy-value perspective. Research has shown that students' perceptions of competence in a STEM field predict their intentions to remain in that field and their choices to take STEM courses during college (e.g., Lent et al., 2003, 2008; Perez et al., 2019). Furthermore, although grades and competence-related beliefs are not the same as one another, grades are the most direct source of information that college students receive about their competence and likely success in a given subject. As such, grades may be a good indicator of competence-related beliefs in an expectancy-value formulation and allow synthesis between different lines of research. Specifically, a large body of research has shown that poor performance in college STEM courses is one of the strongest predictors of attrition from STEM fields (e.g., Chen, 2013; King, 2015; Ost, 2010), particularly in introductory courses that serve as "gateways" to more advanced courses in a major (Maltese & Tai, 2011).

Students' perceptions of the value of STEM fields also influence their likelihood of remaining in these fields (e.g., Perez, Cromley, & Kaplan, 2014; Perez et al., 2019). In particular, college students' interest in a given major or career path is a strong predictor of STEM persistence (e.g., Maltese, Melki, & Wiebke, 2014; Renninger & Hidi, 2016; Renninger, Neilsen, & Nam, 2017; Seymour & Hewitt, 1997; Strenta et al., 1994). In fact, Maltese et al. (2014) found that many students who persisted in STEM in college listed interest in the field as the primary factor determining their persistence (as opposed to getting good grades, social influences, or career/economic opportunities). Seymour and Hewitt (1997) interviewed students who left STEM majors during college and found that students most frequently cited a loss of interest in STEM fields or a growing interest in other fields as their primary reasons for changing plans. Similarly, Strenta et al. (1994) found that more than 85% of students who left science majors agreed with the statement, "I switched out of science because other fields were more interesting" (p. 539).

Demographic Differences

Research on demographic differences in STEM attrition has shown that compared to their peers, African American and Hispanic/Latino/a students, as well as first-generation (FG) college students (i.e., those for whom neither parent has a 4-year college degree) are less likely to pursue STEM majors initially and more likely to drop out of STEM fields during college (Beasley & Fischer, 2012; Chang et al., 2014; National Science Board, 2018; Shaw & Barbuti, 2010). Many researchers have also studied gender differences in STEM attrition (e.g., Cheryan, Ziegler, Montoya, & Jiang, 2017; National Science Board, 2018; Wang & Degol, 2017, for review). However, gender differences in attrition depend on the particular STEM subfield being studied (e.g., physics, biology), and there is no pattern of differential attrition in college for biomedical fields (Cheryan et al., 2017; National Science Board, 2018).

There are many different reasons why URM students or FG college students might be more likely to leave biomedical fields. Of course, the expectancy-value psychological processes outlined above may play an important role. On average, URM students and FG students receive poorer grades than White students and continuing-generation (CG) students in introductory STEM courses, in part because they are more likely to arrive at college with less academic preparation (Chang et al., 2014; Dika & D'Amico, 2016). Lower performance in introductory courses can decrease competence-related beliefs in STEM fields, which can contribute to higher rates of attrition. Moreover, some evidence suggests that URM students can struggle to perceive value in STEM fields (Perez et al., 2019); these trends can further contribute to higher attrition among underrepresented students.

URM and FG students also face unique challenges that may affect attrition independently of their task values and competence perceptions. Students from these underrepresented groups may experience identity threat as a result of perceiving negative stereotypes about the academic performance of their racial or ethnic group (Cohen & Garcia, 2008; Steele & Aronson, 1995; Steele, Spencer, & Aronson, 2002) or socioeconomic background (Harackiewicz et al., 2014; Ostrove & Long, 2007). This experience of threat can heighten daily stress for students who are members of these underrepresented groups, and it can impair their academic performance and undermine their perceptions of belonging in STEM fields (Beasley & Fischer, 2012; Steele et al., 2002; Walton & Cohen, 2007).

Do Students Leave Because of Disenchantment With STEM or Attraction to Other Fields?

The research reviewed above identifies several factors that may cause students to feel disenchantment with STEM fields: (a) perceiving that they are not competent or will not be successful in a given STEM field, (b) perceiving a lack of value or interest for STEM courses or careers, and (c) perceiving a sense of identity threat in STEM classroom or work environments. It is important to mitigate these perceptions, and, indeed, a growing body of intervention research suggests that attrition can be reduced if educators conduct interventions to address these factors (see Harackiewicz & Priniski, 2018; Walton & Wilson, 2018, for reviews). However, an exclusive focus on such factors misses the fact that many students who change majors from STEM fields do not just abandon STEM; if students intend to remain in college, they will switch to another field. Thus, students who are considering switching majors are likely to think both about factors that make them want to leave STEM fields (i.e., factors that make them feel disenchantment) and factors that make them want to pursue alternative fields (i.e., factors that attract them toward non-STEM fields).

All students likely consider the features of both STEM- and non-STEM fields when deciding to change fields of study, and as such all students who leave STEM fields likely feel some disenchantment with STEM as well as some attraction to other fields. However, students may differ in the extent to which they view disenchantment with STEM fields versus attraction to non-STEM fields as more influential on their decision to change plans. That is, some students may think about their attrition primarily in terms of the negative perceptions or experiences in STEM fields that led to feelings of disenchantment. Other students may think about their attrition primarily in terms of positive perceptions or experiences in non-STEM fields that attracted them away. Still other students may think about attraction and disenchantment factors with equal weight. The differences in how students think about their decisions may be consequential, because, as noted above, students who feel attraction toward a non-STEM field may view their attrition from STEM in more positive terms than those who think primarily about their disenchantment with STEM fields. Moreover, these different reasons may have implications for how best to support students. In the present study, we use students' explanations for why they changed plans away from biomedical fields as an indicator of the predominant ways in which they thought about their attrition from those fields, to gain insights regarding how different students' reflections may be distinct from one another.

Eccles (2009, 2013) argued that when students are deciding which academic major or career to pursue, they compare the values associated with different fields of study. Some research has explored this topic empirically, examining how students compare their perceptions of value or competence in STEM fields versus other fields when deciding whether to pursue STEM careers (Diekman, Brown, Johnston, & Clark, 2010; Gaspard, Wille, Wormington, & Hulleman, 2019; Lauermann, Chow, & Eccles, 2015; Ost, 2010; Wang, Eccles, & Kenny, 2013). Most of this work has focused on the negative side of these comparisons (i.e., how relatively low perceptions of value and competence, relative to other fields, make students less likely to pursue STEM), but a few studies have begun to examine how these comparisons might involve students feeling attracted to non-STEM fields. In two studies, researchers found that college students who left STEM fields mentioned the appeal of non-STEM career paths as a primary factor influencing their change of plans (Seymour & Hewitt, 1997; Strenta et al., 1994). In other work, Thoman et al. (2014) found that female students' perceptions of belonging in non-STEM domains predicted their leaving STEM majors. Considered together, this research suggests that, depending on which aspects of STEM/non-STEM comparisons are more salient to students, students might reflect on their attrition from STEM primarily in terms of disenchantment with STEM fields, primarily in terms of attraction to other fields, or as a combination of the two.

Despite this initial work, few studies have examined the prevalence or relative importance of disenchantment versus attraction in students' attrition decision-making processes. As a result, little is known about how frequently students think about leaving STEM fields primarily in terms of disenchantment versus attraction, or whether students who report leaving primarily due to disenchantment differ from those who report leaving due to feeling attraction toward other fields. Furthermore, it is unclear what factors predict students feeling that they left STEM fields for reasons related to disenchantment versus attraction. It is possible that some factors discussed as impacting STEM attrition generally (e.g., poor course performance; demographic differences) are most relevant to predicting students leaving due to disenchantment with STEM fields, and do not predict leaving due to attraction to other fields as strongly.

To our knowledge, the only research to have addressed these types of attraction-disenchantment tensions in STEM attrition directly is a qualitative study in which Seymour and Hewitt (1997) interviewed students who left STEM majors during college. They wrote that some students were "more pulled than pushed" out of STEM fields whereas other students were "more pushed than pulled" (p. 392), but they did not test factors that might predict leaving the field for these different reasons. They described students who were more pulled than pushed as being multitalented and having continued interest in STEM fields, but ultimately leaving STEM because they were drawn to more fulfilling majors. In contrast, students who were more pushed than pulled were described as being discouraged by their STEM courses; the authors noted that many students of color fell into this category. Their study provides compelling initial insights into how students think about both STEM and non-STEM fields when making attrition decisions, but such findings would be complemented by further study using a more quantitative approach.

The Present Study

The present study examined students' explanations for leaving one important category of STEM fields—the biomedical fields—with a goal to shed light on attraction and disenchantment dynamics in this area. Biomedical fields play a critical role in driving medical advances that can vastly improve public health and well-being (Finkelstein, Hambrick, & Cannella, 1996; National Institutes of Health, 2015). It is important to ensure that a larger and more diverse pool of individuals pursue biomedical courses of study to ensure continued innovation in this area. We interviewed students about their majors and future plans approximately 2 years after the end of an introductory biology course taken by biology and prehealth majors; we then classified which students had stopped pursuing biomedical fields of study since the semester in which they took the biology course. Among the students who left biomedical fields, we examined whether students discussed their leaving primarily in terms of disenchantment with biomedical fields or in terms of features of different fields that attracted them away.

The study had two main goals: description and prediction. With respect to the first goal, we examined the nature and prevalence of students' reasons for leaving biomedical fields of study during college in order to shed light on attraction and disenchantment reasons for leaving. Our specific research questions for this portion of the study were: (a) What proportion of students explained their leaving primarily in terms of feeling disenchantment with biomedical fields, attraction toward other fields, or both?; (b) What specific topics did students discuss when they talked about leaving due to feeling disenchantment or attraction?; and (c) How did students who stayed versus left, or who left due to disenchantment versus attraction reasons, compare on demographic and psychological variables?

The second goal of the study was predictive: (a) to study several predominant predictors of attrition in this context and (b) to test

whether the same factors that predict biomedical attrition in general also predict students' likelihood of leaving biomedical fields for reasons related to disenchantment or attraction. We tested whether demographic characteristics (URM and FG status, gender), achievement prior to and in an introductory biology course, and interest at the beginning and end of an introductory biology course predicted attrition from biomedical fields, as well as attrition due to feeling disenchantment with biomedical fields and/or attraction toward nonbiomedical fields. Although our study is grounded in expectancy-value theory, we focused on course grades as a predictor of attrition rather than competence-related beliefs. This was because grades are the measure more frequently used as a predictor of attrition in prior research (e.g., Chen, 2013) and we wanted our results to be directly comparable to this large body of prior work.

Method

Participants

Participants were 1,264 students who had been enrolled in an introductory biology course at a large Midwestern university between Fall 2011 and Spring 2014, and who consented to complete a follow-up interview about their career plans between Spring 2014 and Summer 2017. Participants in the final sample (n = 1193 of these 1264, see Measures section for details) were 64.0% female, 72.5% White, 13.0% Asian/Asian American, and 14.5% URM (i.e., African American, Hispanic/Latino/a, or Native American); 36.5% of participants were FG students (i.e., they reported that neither parent had obtained a 4-year college degree). This introductory biology course served as a critical prerequisite for many biomedical majors at the university (e.g., nursing, biochemistry, zoology).

The 1,264 interviewed students represented 68.8% of a broader sample (1837 students) who had participated in one of two intervention studies exploring students' motivation and performance in introductory biology courses. One study enrolled students who took the course during Fall 2011 (n = 798; see Harackiewicz et al., 2014, for details); the other enrolled a subsample of students who took the course between Fall 2012 and Spring 2014 (n = 1,039; see Harackiewicz, Canning, Tibbetts, Priniski, & Hyde, 2016, for details). We aimed to recruit as many students as possible from the two studies and obtained a sample that was representative of them in terms of demographic variables and course achievement; see Table 1 for a comparison of students in the present study to students from the original samples. In both studies, some students in the course received interventions that aimed to enhance their motivation for learning biology, whereas other students did not. Both interventions tested in these studies (a utility-value intervention and a values-affirmation intervention) successfully promoted underrepresented students' performance in the biology course (see Harackiewicz et al., 2014, 2016, for details). The long-term effects of both interventions have been reported in previous papers (Hecht et al., 2019; Tibbetts et al., 2016). In the present study, we combined interview samples (which each represented a subset of the total sample from the respective intervention study) to maximize the sample size for our analyses of student interviews. We control for study and experimental condition in all statistical models.

Procedure

Students completed questionnaires measuring their interest in learning biology at two time points. A baseline questionnaire was administered at the beginning of the introductory course, during which students also reported their intended majors and graduate school plans. A second questionnaire was administered at the end of the course.

Between Spring 2014 and Spring 2017, participants from both research projects were contacted to complete a follow-up interview about their academic major, career goals, and future plans. Most, but not all, students took the biology course as sophomores, and students finished their college degrees at different rates. We contacted students for interviews at time points as close to their graduation as possible, so the time that elapsed between the introductory biology course and the interview differed across students (M = 5.73 semesters, SD = 1.16, range = 2 to 9 semesters). Participants who consented to participate responded to a set of

Table 1
Comparison of Interviewed Students to Samples From Original Studies

Variable	Final sample of interviewed students (n = 1,193) Freq. (%) or M (SD)	Sample in 2012–2014 study (n = 1,039) Freq. (%) or M (SD)	Sample in 2011 (n = 798) Freq. (%) or M (SD)
Gender			
Male	430 (36.0%)	415 (39.9%)	320 (40.1%)
Female	763 (64.0%)	624 (60.1%)	478 (59.9%)
URM status			
URM	173 (14.5%)	190 (18.3%)	61 (7.6%)
Majority	1,020 (85.5%)	849 (81.7%)	737 (92.4%)
FG status			
First-generation	435 (36.5%)	491 (47.3%)	154 (19.3%)
Continuing-generation	758 (63.5%)	548 (52.7%)	644 (80.7%)
Biology course grade	2.88 (0.72)	2.78 (0.81)	2.77 (0.73)

Note. URM = underrepresented racial/ethnic minority; FG = first-generation. Although 1264 students were interviewed, only 1193 intended to pursue biomedical fields of study at baseline and thus comprised the final sample for this study.

open-ended questions about their majors and future plans, either during a phone interview or, if that was not possible, via an online survey system (see Table 2). Participants described what their majors were (either currently or, if they had graduated, at graduation), what their future plans were for the 2-year period following the interview and 10 years later, whether their future plans had changed since they had taken the introductory Biology course, and why their plans changed if they did change. Participants received a gift card in exchange for completing the interview.

To supplement the information from the interviews and questionnaires, we collected data from institutional records regarding students' grades in the introductory course, choice of major four semesters after taking the introductory course (or at graduation), and demographic information.

Measures

Biomedical attrition and retention. To classify those who dropped out of biomedical fields of study versus those who remained, we created an index of whether students stopped pursuing biomedical fields of study between the point when they took the introductory biology course and two years after they completed the course. We used multiple sources of data to classify students' fields of study at baseline and 2 years later. In terms of initial fields of study, students reported their major or intended major on the baseline questionnaires, and they also checked one or more boxes to indicate if they intended to pursue one of five preprofessional tracks that were biomedical in nature (i.e., premed, prevet, predental, prepharmacy, or preoptometry). We classified students as being in the biomedical field at baseline if students reported that they were pursuing a biomedical major on the baseline questionnaire, or if students checked any of the preprofessional career boxes on the baseline questionnaire. We classified particular majors as biomedical or not based on criteria set by Hecht and colleagues (2019); students with multiple majors were classified as being in the biomedical field if any of their majors was biomedical in nature.

Table 2
List of Questions Asked During Interviews

Question
1. Have you graduated yet? When did you graduate/when do you plan to graduate?
2. What is/are your majors?
3. What are your plans after graduation?
4. What do you expect to be doing next fall?
5. What do you expect to be doing the following fall?
6. What job or career do you hope to have in 10 years?
7. Are your career plans different now compared to what they were when you started introductory biology?
8. [if plans changed]: How, why, and when did your career plans change?
9. Why are you pursuing your current career goals?
10. Please list three reasons you find this career attractive.
11. Is there anything else you would like to tell us about your experience here at [university name]?/ How would you describe your overall experience here at [university name]?

Note. Wording of questions differed slightly across students; during interviews conducted in 2014 (n = 110). Questions 4,5,9, and 10 were omitted and students completed several alternative questions.

To classify students' fields of study 2 years after completing the biology course, we examined institutional records showing students' declared majors either four semesters after they completed the introductory biology course or at graduation (if they graduated before four semesters had passed). If institutional records did not indicate a major for a given student at the follow-up time point, we examined what students stated their majors were in their interviews. We classified students as having remained in a biomedical field during the 2-year time period following the baseline time point if either (a) they were pursuing a biomedical major at baseline and were still pursuing a biomedical major at the follow-up time point, or (b) they had indicated that they were pursuing one of the five preprofessional career tracks noted above and were still planning on pursuing that career track at the follow-up time point. Students who were not still pursuing biomedical majors or preprofessional paths at the follow-up were classified as having left biomedical fields of study.

Results showed that of the 1,264 students in the sample, the vast majority (n = 1,193; 94.4%) began the course intending to major in a biomedical field, and this group of 1,193 students constitutes the final sample for this study. Most of these students (n = 1,001, 83.9%) also remained in biomedical fields at follow-up, but 192 students (16.1%) were classified as having left biomedical fields, either because they had switched to STEM majors that were not biomedical (n = 46, 24.0% of leavers) or because they switched to non-STEM majors (n = 146, 76.0% of leavers). The nonbiomedical majors that the students in our sample pursued at the follow-up time point encompassed a wide range of subjects (e.g., Spanish, economics, classical humanities, education, art, journalism, legal studies, mechanical engineering, social welfare, international studies).

Coding students' explanations for leaving biomedical fields. After leavers were identified, two teams of trained coders coded these students' explanations for leaving in terms of two variables. The first, disenchantment versus attraction, classified a student's reason for changing their plans as being primarily related to attraction toward nonbiomedical fields (i.e., something about their new major/career plan that drew them away from biomedical fields) or disenchantment with biomedical fields (i.e., something about their original major/career plan, or their negative perceptions of the field, that caused them to leave). Students could also be classified into a third "both" category if they described disenchantment and attraction factors with equal weight (κ = .75 between the two teams; see Table 3 for details).[1] The critical dimension of interest in this study was whether students discussed their attrition in terms of feeling disenchantment with the biomedical field they were leaving behind or attraction toward the new field they were pursuing. Attraction and disenchantment reasons could be grounded in experiences that were either external or internal to the

[1] The interrater agreement statistic reported in this article is a Cohen's Kappa (Cohen, 1960). The correspondence between Kappa values and percentage agreement between raters differs as a function of the number of codes being used and the frequency with which different codes occur (Bakeman & Quera, 2011). A conservative estimate of the Kappa value required to reach a certain threshold of inter-rater agreement would be the point at which these values reach an asymptote (i.e., when code number and prevalence do not strongly affect the correspondence between Kappa and agreement). To ensure 85% agreement between coders, the corresponding asymptotic value of Kappa would be .70, which was the threshold we adopted in the present study.

Table 3
Coding Scheme for Interviews

Category	Sample response
Attraction vs. disenchantment	
"Attraction": associated with nonbiomedical field	"The semester after Bio, I decided I was more inclined to pursue international law. I like discussing world events and learning about humanities more than the sciences . . ."
"Disenchantment": associated with biomedical field	"I started out pre-Med then switched to pre-Law. I realized that becoming a doctor wasn't the right plan for me . . . primarily due to poor performance and lack of interest in Organic Chemistry courses and higher level Calculus . . ."
How plans changed	
Interest/value	"[My plans] changed my junior year because I did not enjoy my classes and was not happy with my decision to major in biology."
Confidence/ability	"I struggled with the class and did not feel a career in the biology field was right for me."
Barriers and obstacles	"I withdrew from college the Spring 2014 semester, as a result of family death and health issues. To finish in time I switched majors."
Interpersonal factors	"Even though I like learning about biology, I don't like working with people in the hard sciences."
Other	"I had not figured out what I was going to do at that time."

student. For example, a student could feel disenchantment with biomedical fields because the instructor of a course told them they were not capable of success, or because they realized that they no longer valued their biology career. A student could feel attracted toward nonbiomedical fields because someone in their new field of study encouraged them to switch, or because they decided another career was more rewarding.

The second variable, how plans changed, addressed the specific topics students discussed when talking about leaving biomedical fields. The first author and two research assistants read all 192 responses of students who left biomedical fields and together they discussed students' responses regarding why their future plans changed in order to reach consensus on the primary themes that students mentioned. Four themes emerged: (a) confidence and/or ability, (b) value of or interest in a certain career or major, (c) interpersonal factors, and (d) costs and barriers that prevented students from pursuing certain career paths (see Table 3 for details). These themes could be related to either attraction or disenchantment reasons for changing plans; for example, a student writing about the theme of value or interest might have mentioned their loss of interest in their original major (which relates to disenchantment), or a growing interest in a new major (which relates to attraction). After identifying these four themes, two teams of trained coders classified which theme matched each student's response most closely ($\kappa = .77$).

For both types of coding, there was an option for coders to designate a response as "other" or "vague." If this occurred, the first and second author examined the response and reached consensus on how to classify it (i.e., they determined whether it was indeed impossible to code it, or whether it could be classified into one of the categories described above).

Perceived interest in learning biology. Students' perceptions of interest in biology were measured at the beginning and end of the introductory biology course using 7-point scales adapted from prior research (Harackiewicz et al., 2016). We created an average score across five items (see the online supplemental materials for complete list of items; sample item: "Biology fascinates me."; $\alpha = .91$ at baseline, .92 at end of course).

Prior achievement. Consistent with procedures used by Harackiewicz et al. (2014, 2016), we computed a measure of students' prior achievement based on either college grade point average or, when not available, standardized test scores (see the online supplemental materials for more information).

Biology course grades. Students' grades in the introductory biology course were collected from institutional records. Instructors calculated grades from students' performance in lecture, discussion, and laboratory sections including multiple-choice and short-answer exams and quizzes (60%), laboratory activities (35%), and discussion activities (5%). Course coordinators worked to ensure standardization of content and grading procedures across both sections within a course and across different semesters of the course. Grades were assigned on a 4.0 scale, with students who earned grade percentages that were close to the cutoff points earning an intermediate grade designation (e.g., students whose scores were between the A and B range earned an AB, and students whose score were between a B and a C earned a BC). The grade cutoff points were as follows: A = 90–100% (4.0 grade points), AB = 88–89.99% (3.5 grade points), B = 80–87.99% (3.0 grade points), BC = 78–79.99% (2.5 grade points), C = 70–77.99% (2.0 grade points), D = 60–69.99% (1.0 grade points) and $F = <60\%$ (0 grade points). Course grades were not curved.

Demographic data. Demographic information regarding students' generational status, URM status, and gender was collected using a combination of self-report and institutional records.

Analytic Strategy

The study had both descriptive and predictive goals. Our descriptive goals were to examine the nature and prevalence of students' reasons for leaving biomedical fields of study during college. We examined (a) the proportion of students who explained their leaving primarily in terms of feeling disenchantment with biomedical fields, feeling attraction to other fields, or both; (b) the topics that students discussed when they talked about feeling disenchantment or attraction; and (c) group differences between students who stayed in versus left biomedical fields, and between students who left biomedical fields due to reasons related to disenchantment versus attraction.

The predictive goals of the study were to examine whether students' demographic characteristics (URM and generational status, gender), achievement prior to and in an introductory biology course, and interest at the beginning and end of an introductory

biology course predicted attrition from biomedical fields. We first examined what factors predicted overall attrition from biomedical fields using binary logistic regression (attrition = 1; retention = 0). We then examined whether the same factors predicted two distinct subsets of overall attrition—attrition due to feeling disenchantment with biomedical fields, or attrition due to feeling attraction toward nonbiomedical fields—using multinomial logistic regression, with remaining in biomedical fields as the reference group. For all regression analyses we used a two-step predictive model in MPlus (Version 7) with full information maximum likelihood estimation for missing data (<1.4% on all variables). Step 1 included demographic predictors only: gender (1 = male; −1 = female), URM status (1 = member of an URM group: African American, Hispanic/Latino/a, or Native American; −1 = not a member of an URM group), and generational status (1 = FG student, −1 = CG student). Step 2 added psychological predictors: students' interest in biology measured at baseline, interest in biology measured at the end of the introductory course, prior achievement, and grades in the introductory biology course (all standardized). Expectancy-value theory predicts that effects of interest on academic motivation will be stronger among students with higher perceptions of their competence or higher grades (Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008; Nagengast et al., 2011; Wigfield, Rosenzweig, & Eccles, 2017). We included interactions between baseline interest and prior achievement, and between interest measured at the end of the introductory course and biology course grades, in the predictive models to account for any potential interactive effects between competence-related and value-related measures.[2]

Results

Classifying Whether Students Left Biomedical Fields Due to Disenchantment or Attraction

Descriptive statistics regarding the coding of interview responses can be found in Table 4. Among the 192 students who left biomedical fields, 45 (23.4%) provided responses that were too brief or vague to classify as being distinctly related to disenchantment or attraction (e.g., "My plans changed after sophomore year when I switched my major."). Among the remaining students, 110 (74.8%) articulated at least one reason for leaving biomedical fields that was related to the fields themselves (i.e., a factor causing them to feel disenchantment with biomedical fields), and 55 (37.4%) articulated at least one reason for leaving biomedical fields that was related to another field (i.e., a factor that caused them to feel attraction toward nonbiomedical fields). Ninety-two students (62.5%) described only "disenchantment" factors in their explanations of why their plans changed, 37 students (25.2%) described only "attraction" factors, and 18 students (12.2%) described both types of factors with equal weight.

Exploring Students' Reasons for Feeling Disenchantment or Attraction

Table 4 also provides information about the themes and topics that students referenced most frequently in their explanations for leaving the biomedical field.[3]

Students who left due to disenchantment. Among the 92 students who explained their change in plans exclusively in terms of disenchantment with biomedical fields, 44 (47.8%) mentioned a lack of interest or value as their primary reason for changing plans. For example, one student wrote, "I initially wanted to attend medical school after my undergraduate education and become an infectious disease physician. However, I lost interest in this track because of the pre-med undergraduate courses I was taking—I was bored by my biology and chemistry classes." Most students in this group referenced interest- or fit-related experiences, as opposed to experiences related to job rewards or opportunities. For example, students referenced courses they perceived to be boring, career plans in which they lost interest or perceived did not fit them well, or a lack of satisfaction and/or passion for their original major or career plan.

Thirty students who explained leaving only in terms of reasons related to disenchantment (32.6%) referenced confidence or ability as the primary reason for changing their plans away from biomedical fields. These students often expressed one of two reasons for changing plans. Some students indicated that they would be unable to meet the admissions requirements for graduate school in a chosen career. For example, one student wrote, "My career plans changed because I did not succeed in my science courses enough to be able to enter physician assistant school after graduating. I do not have high enough grades in my core science classes to apply." Other students indicated that poor performance in prerequisite courses for a STEM major drove them away from biomedical fields. A student stated,

> Intro Biology proved to be a "weed out" class for me. I had been struggling with what I wanted to do, being a teacher was always in the back of my mind but everyone in my family are teachers and I wanted to try a different route. This class was a huge challenge to me and I learned early on at the beginning of this class that it was not meant for me.

In some cases, issues of interest/value and confidence/ability interacted to affect students' decisions. For example, one student described how his poor performance outweighed his initial interest in the course: "I started out pre-med and then switched to pre-law. I realized that becoming a doctor wasn't the right plan for me (although I did enjoy biology courses) primarily due to poor performance and lack of interest in organic chemistry courses and higher level calculus." Another student described course difficulty

[2] We controlled for whether students were in intervention versus control conditions in all regression analyses, along with which sample students were part of, using a set of orthogonal contrast codes. We report the results of these codes in the online supplemental materials, but we omit them from the manuscript text because the results are not central to the present research questions, do not accurately represent long-term intervention effects (because we did not interview everyone who participated in the intervention studies), and there were no meaningful patterns of results when examining these codes. We also ran the analysis on overall attrition including only the students who were in the control conditions in both studies (n = 540). We did not have sufficient power for these analyses, due to the smaller sample, but we obtained similar patterns of results (see online supplemental materials for complete description of these analyses).

[3] Any specific references to course names in the quotations noted below have been changed to more generic terms to protect anonymity. We have also made very minor changes to some quotations to improve grammar and readability.

Table 4
Results of Interview Coding

	How plans changed					
Attraction vs. disenchantment	Interest/value	Confidence/ ability	Barriers and obstacles	Interpersonal factors	Other	Total
Only attraction	35	0	0	0	2	37
Only disenchantment	44	30	10	3	5	92
Both attraction and disenchantment	11	4	2	0	1	18
Total	90	34	12	3	8	147
Not enough information to classify	—	—	—	—	—	45

as negatively affecting interest: "My plans changed because biology classes at [university name] are nearly impossible and made me no longer interested in pursuing a science-related degree."

Finally, 10 students (10.9%) indicated that they left primarily because of costs or barriers associated with biomedical majors or career paths. These students either reported that they had external barriers that made the biomedical degree seem much more challenging (e.g., a death in the family) or articulated that they did not believe that the time, cost, or psychological toll of pursuing a particular biomedical career was worth it. For example, one student wrote, "My plans changed because I didn't want to spend that many more years in school going to medical school." Another student expressed, "Medical school. That's really all I need to say. . . . Although I do love the sciences and my desire to help Latinos and other underrepresented groups in the community is still a huge part of who I am, there was only a certain point I could mentally go."

Students who left due to attraction. When students discussed leaving due to feeling attraction toward nonbiomedical fields, their responses were almost all about interest in or value for new majors or career paths (n = 35 out of 37 students who discussed attraction reasons for leaving, with the other two students' responses being too vague to classify). For some students, coursework attracted them away from the biomedical field. One student wrote, "I used to want to go into the medical field—mainly as a physician's assistant. However, I was taking Intro Sociology concurrently with Intro Biology and I fell in love with Sociology and then decided to major in that." Another student stated, "My plans changed because I discovered my passion for creative writing." For other students, the positive aspects of various career paths drew them away. One student wrote, "I was planning on applying to medical school but as I gained more experience in the psychology field and direct patient care I changed my focus toward obtaining a Ph.D." Similar to students who expressed disenchantment, the vast majority of students who expressed leaving due to attraction discussed their change in terms of interest- and fit-related experiences rather than job rewards or opportunities.

The majority of students in the "attraction" group articulated that at some point between baseline and follow up they had clear initial career plans. However, there was a small subgroup of students (n = 8) who expressed being somewhat undecided about their initial career plans prior to feeling attracted to nonbiomedical fields. These students stated that they had either a weak commitment to an initial profession (e.g., "I took the Intro Bio 151 course as a prerequisite for optometry school or other similar medical degree, just to keep my options open") or a complete lack of commitment to initial career plans, despite having reported interest in a biomedical major at the baseline time point (e.g., "I had not figured out what I was going to do at that time"). For these students, initial uncertainty about their career plans may have made them more open to perceiving attractive features of alternative fields.

Students who left due to both disenchantment and attraction. Among the 18 students who expressed both disenchantment and attraction factors in their explanations of why they left biomedical fields, 11 students (61.1%) referenced topics related to interest or value. Similar to the other groups, these students often discussed interest- and fit-related experiences as opposed to experiences related to job rewards and opportunities. In particular, many students referenced both a loss of interest in a biomedical field and a growing interest in another major or career path. For example, one student stated,

> I was interested in psychology research or becoming a doctor (specifically a psychiatrist) but just found myself losing interest in those two things as long-term career paths. . . . Meanwhile, for the business certificate, I was required to take economics courses. I found myself very intrigued by these, but realized that in order to be able to do economic research, I would need a much stronger background in mathematics and statistics. Finding myself particularly interested in forecasting and prediction, I have decided statistics is the way to go, and I really do love it.

Among the students referencing interest or value, there was wide variation in the order with which students reported experiencing disenchantment versus attraction; that is, it was not the case that all students first experienced disenchantment and then attraction. Five students reported that a loss of interest or perceived fit in their initial field of study caused them to search for alternative options, after which point they considered positive aspects of alternative fields. For example, one student expressed, "After completing biology and organic chemistry, I decided med school was not for me and decided to pursue my interest in counseling psychology." However, two students expressed that positive experiences in the new field of study drove them to realize that they were dissatisfied with their original majors or career plans. In addition, four students described their change in plans as simultaneous, stating that at some point they decided that their interests were better aligned to one field of study versus another. For example, one student stated, "I decided that I was no longer interested in the sciences as much as I used to be and I realized that I really loved serving people through various avenues and relationships."

Finally, four students (22.2%) in this group noted that experiences related to confidence or ability were the central reason behind their change in plans. Three students' quotations stated that low perceptions of competence or low ability were the primary determinant of their plans changing, after which point they discovered another field that they liked. For example, one student who originally intended to major in biology wrote, "Chemistry was difficult for me and was the major reason I switched. I ended up taking a social work class and loved it." The other student reported that they had poorer performance than expected on their biology coursework and they simultaneously discovered a growing interest in public health.

Summary of coding results. Most students leaving biomedical fields explained their choice in relation to interest or value, referencing in particular concepts related to interest and fit. This was especially true when students expressed leaving due to attraction toward nonbiomedical fields. Among students who described leaving due to disenchantment with biomedical fields, both interest/value and concerns about confidence or ability were prominent sources of influence. This coding also revealed that students who reported both disenchantment and attraction reasons for leaving were similar to students who gave only attraction-related reasons for leaving in that they discussed attrition in relatively positive terms. We therefore included the 18 students who reported both types of reasons for leaving with the "attraction" group in subsequent analyses.

Group Differences: Stayers Versus Leavers and Students Who Left Due to Disenchantment Versus Attraction

In a final step of the descriptive data analyses, we examined how students who remained in biomedical fields compared to students who left, and (among the students who left) we examined how students who left due to disenchantment compared to students who left due to attraction toward nonbiomedical fields. Specifically, we tested for demographic differences (URM status, generational status, and gender) and mean differences on psychological variables (interest in biology, prior achievement and biology course grades).

We tested for these differences using orthogonal contrast codes, using linear regression to predict mean scores on the psychological variables and logistic regression to predict likelihood of membership in a certain demographic group for the demographic variables. All regression models included two contrasts: (a) stayed versus left, which compared students who stayed in biomedical fields (coded as -3) to all students who left biomedical fields (those who left due to disenchantment, those who left due to attraction, and those who left due to reasons that were too vague to classify, each coded as $+1$), and (b) disenchantment versus attraction, which compared students who left biomedical fields primarily due to disenchantment (coded as $+1$) to students who left primarily due to attraction (coded as -1); students who remained in biomedical fields or who left but gave responses too vague to classify were coded as 0.[4] Students who gave both disenchantment and attraction reasons for leaving were included in the "attraction" group. Because we examined a group of several correlated psychological variables (interest and performance, each measured at two time points), we adjusted the alpha threshold to reduce the possibility of Type I error. Specifically, we adopted a Bonferroni adjustment to our significance threshold across this group of four tests. Thus, for regression models predicting the psychological variables, our alpha threshold for significance was .05/4, or .0125.

Correlations among all variables are reported in Table 5, and descriptive statistics comparing students who remained in biomedical fields, students who left due to disenchantment-related reasons, and students who left due to attraction-related reasons are reported in Table 6. Results of the contrast code analyses are reported in full in the online supplemental materials. Analyses demonstrated that students who left biomedical fields reported significantly lower interest in biology at the end of the semester, $b = -0.14$, $z = -6.10$, $p < .001$, had lower prior achievement, $b = -0.11$, $z = -5.40$, $p < .001$, and received lower biology course grades, $b = -0.13$, $z = -8.98$, $p < .001$, compared to students who remained in biomedical fields. There were no differences in FG status or gender, $|zs| < 1.70$, $ps > .09$, or in baseline interest, $z = -2.23$ $p = .026$, between students who remained in versus left biomedical fields.

There was one significant difference between students who left due to disenchantment versus attraction reasons: URM students were more likely to report leaving due to disenchantment than attraction, $b = 0.51$, $z = 2.03$, $p = .04$, odds ratio [*OR*] = 1.66. There were no significant differences on gender or FG status, $|zs| < 0.91$, $ps > .361$, or on any of the psychological variables, $|zs| < 2.20$, $ps > .028$.

Predicting Attrition From Biomedical Fields

The group comparisons suggested that there were systematic differences between students who stayed in biomedical fields and those who left, particularly in terms of interest and performance in biology courses. A related, but distinct, question is how these different factors predicted students' attrition from STEM fields, controlling for the other factors. We therefore tested what factors predicted overall attrition in our sample and compared our results to those that have been reported in previous studies. To compare our results most directly with extant literature regarding demographic differences in attrition, we first predicted attrition using only demographic characteristics (URM status, FG status, and gender). We then predicted attrition using models that included psychological variables (i.e., interest and achievement) as well as demographic characteristics. Based on prior research, we expected to find that students' URM and FG status (but not gender) would predict attrition from biomedical fields in the demographic models, and achievement in introductory biology courses and interest in biology would predict attrition in models including psychological variables.

Table 7 presents the results of logistic regression analyses predicting attrition from demographic variables. URM students were more likely to leave biomedical fields, $b = 0.22$, $z = 2.16$, $p = .03$, $OR = 1.25$; 22.5% of URM students left biomedical fields as compared to 15.0% of majority students. This finding is con-

[4] To exhaust the degrees of freedom for this four-group analysis, we also included a third contrast, vague vs. specific reason for leaving, which compared students who left biomedical fields but did not provide a clear reason for leaving ($+2$) to students who left due to feeling either disenchantment (-1) or attraction (-1), with results presented in the online supplemental materials.

Table 5
Descriptive Statistics and Correlations

Variable	1	2	3	4	5	6	7
1. Gender							
2. URM status	−.04						
3. FG status	−.05	−.02					
4. Prior achievement	.01	−.11**	−.14**				
5. Biology course grade	.11**	−.17**	−.15**	.59**			
6. Baseline interest in biology	−.01	.02	.02	−.06	.03		
7. Interest in biology after intro course	.01	.02	−.03	−.01	.19**	.64**	
M	—	—	—	0.00	2.88	5.83	5.49
SD	—	—	—	1.00	0.72	0.97	1.18

Note. URM = underrepresented racial/ethnic minority; FG = first-generation. Gender: Male = +1, Female = −1. URM status: URM = +1, Majority = −1. FG status: FG = +1; continuing-generation = −1. Table 1 reports frequency statistics for gender, URM status, and FG status.
** $p < .01$.

sistent with previous research. Gender did not predict students leaving biomedical fields in this sample; 13.7% of male students left biomedical fields as compared to 17.4% of female students. Inconsistent with previous research, generational status did not predict attrition in our sample; 16.3% of FG students left biomedical fields as compared to 16.0% of CG students.

We next predicted attrition using both demographic and psychological variables. In this model, the effect of URM status was no longer significant, but FG status was a significant predictor, $b = -0.19$, z = −2.03, $p = .04$, $OR = 0.83$, such that FG students were less likely to leave biomedical fields after controlling for the psychological variables. Consistent with our predictions, students' interest, measured at the end of the introductory biology course, negatively predicted their likelihood of leaving biomedical fields, $b = -0.57$, z = −5.10, $p < .001$, $OR = 0.57$, as did their grades earned in the introductory course, $b = -0.61$, z = −5.61, $p < .001$, $OR = 0.54$. This suggests that, controlling for baseline interest and prior achievement students who were more interested in biology at the end of the course and students who received higher grades were less likely to leave biomedical fields. These predictors were equally strong, as shown in Figure 1. Neither students' interest measured at baseline, nor their prior achievement, predicted attrition. The interactions between students' baseline interest and prior achievement, and end-of-semester interest and biology course grades, also were not significant.

Process analysis: Do differences in grades or interest help explain why URM students left biomedical fields at higher rates? Results suggested that URM students were more likely to leave biomedical fields compared to majority students; however, these effects were no longer significant after controlling for psy-

Table 6
Differences Between Students Who Stayed, Left Due to Disenchantment, and Left Due to Attraction

	Remained in biomedical fields (n = 1,001)	Left due to disenchantment (n = 92)	Left due to attraction (n = 55)
Variable	Freq. (%) or *M* (*SD*)	Freq. (%) or *M* (*SD*)	Freq. (%) or *M* (*SD*)
Gender			
Male	371 (37.1%)	30 (32.6%)	15 (27.3%)
Female	630 (62.9%)	62 (67.4%)	40 (72.7%)
URM status[b]			
URM	134 (13.4%)	25 (27.2%)	6 (10.9%)
Majority	867 (86.6%)	67 (72.8%)	49 (89.1%)
FG status			
FG	364 (36.4%)	31 (33.7%)	20 (36.4%)
Continuing-generation	637 (63.6%)	61 (66.3%)	35 (63.6%)
BL achievement[a]	0.08 (0.98)	−0.55 (0.89)	−0.45 (1.13)
EOS biology grade[a]	2.97 (0.68)	2.29 (0.74)	2.55 (0.74)
BL interest in biology	5.59 (1.12)	5.65 (1.14)	5.84 (0.90)
EOS interest in biology[a]	5.86 (0.95)	4.82 (1.34)	5.08 (1.25)

Note. URM = underrepresented racial/ethnic minority; FG = first-generation; BL = baseline; EOS = end of semester in which students took introductory biology course. All comparisons of significance are based on a set of orthogonal contrast codes used to predict each variable on the left-hand side of the table from attrition group status (controlling for whether or not students received interventions and for which of the two studies in this sample students completed). See online supplemental materials for complete output from the analyses.
[a] Indicates that those who remained in biomedical fields differed significantly from those who left biomedical fields on the indicated variable. [b] Indicates that those who left due to disenchantment with biomedical fields differed significantly from those who left due to attraction towards non-biomedical fields on the indicated variable.

Table 7
Likelihood of Attrition From Biomedical Fields

Predictor	B	*SE*	z	Sig.	*OR*	B	*SE*	z	Sig.	*OR*
Intercept	−1.57	0.11				−1.93	0.14			
Gender	−0.14	0.09	−1.59	.112	0.87	−0.10	0.09	−1.07	.287	0.91
FG status	−0.03	0.09	−0.32	.748	0.97	−0.19	0.09	−2.03	.043	0.83
URM status	0.22	0.10	2.16	.031	1.25	0.06	0.11	0.53	.596	1.06
BL achievement						−0.19	0.10	−1.88	.061	0.83
BL interest						0.14	0.10	1.37	.172	1.15
Biology course grade						−0.61	0.11	−5.61	<.001	0.54
EOS interest						−0.57	0.11	−5.10	<.001	0.57
BL Interest × BL Achievement						−0.01	0.08	−0.16	.876	0.99
EOS Interest × Biology Grade						−0.15	0.08	−1.88	.060	0.86

Note. URM = underrepresented racial/ethnic minority; FG = first-generation; *OR* = odds ratio; BL = baseline; EOS = end of semester in which students took introductory biology course. n = 1,193; missing data addressed using full information maximum likelihood estimation. All models control for whether or not students received interventions and for which of the two studies in this sample students completed; see online supplemental materials for details. Gender: Male = +1, Female = −1. URM status: URM = +1, Majority = −1. FG status: FG = +1; continuing-generation = −1.

chological variables. Given that low biology grades and low interest in biology at the end of the semester were both associated with attrition from biomedical fields, we tested whether URM students' higher likelihood of attrition could be explained in part by either of these factors. We first used regression analyses to test whether URM students received lower grades in the biology course or reported lower interest in biology at the end of the semester, compared to majority students. Results suggested that URM students did not report significantly lower interest in biology, $\beta = -0.02$, $p = .495$, but they did receive significantly lower grades, $\beta = -0.18$, $p < .001$ (see Table 8).

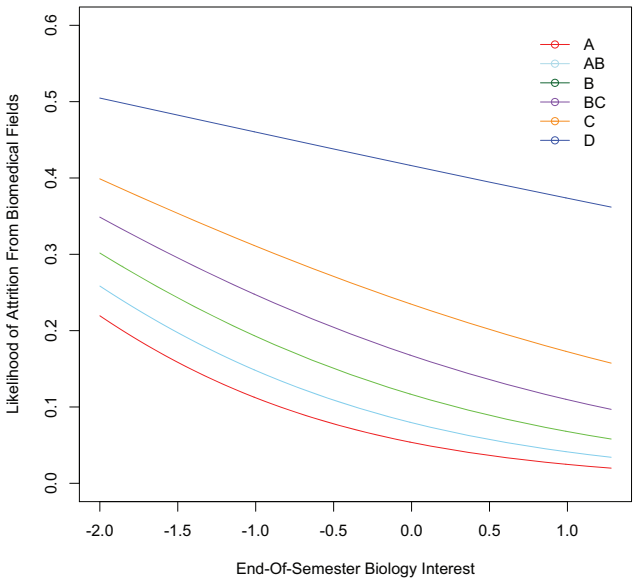

Figure 1. Relation between interest in biology at the end of the introductory course (standardized, plotted up to the maximum value of 1.28) and likelihood of attrition from biomedical fields, estimated at different course grades (grade distribution across students is as follows: A, n = 167; AB, n = 120; B, n = 534; BC, n = 109; C, n = 218; D, n = 42; *F*, n = 3). See the online article for the color version of this figure.

We next tested whether URM students were more likely to leave biomedical fields as a function of receiving lower grades, using the "model indirect" function in MPlus with URM status as the independent variable, biology course grade as a process variable, and likelihood of attrition from biomedical fields as the outcome variable (we included as covariates all of the predictors from the regression model on attrition). The results of this test produced an estimate of the indirect effect of URM status on the likelihood of leaving biomedical fields through biology course grades, which was significant (estimate = 0.09; bootstrap *SE* = 0.03, z = 3.64, $p < .001$). This suggests that URM students received lower grades in the biology course compared to majority students, which was in turn associated with higher attrition from biomedical fields.

Predicting Different Kinds of Attrition

Our descriptive analyses identified distinct groups of leavers, particularly those who thought about leaving primarily in terms of disenchantment with biomedical fields, and those who thought about leaving primarily in terms of attraction toward nonbiomedical fields. We next examined whether the same factors that predicted overall attrition predicted each distinct subtype of attrition. That is, we examined what factors predicted students leaving biomedical fields primarily because they felt disenchantment, or because they felt attraction to other fields, compared to students who stayed in biomedical fields. We conducted a multinomial logistic regression, which allowed us to compare the likelihood of students reporting each type of reason for attrition (disenchantment, attraction) compared to remaining in biomedical fields as the reference group.[5] To include the whole sample in this analysis, we included students who left but did not provide a clear reason for leaving as a third category (in addition to the categories of disenchantment and attraction). As noted earlier, we included students

[5] The significant multinomial regression effects reported here remained significant if we ran separate logistic regression models (disenchantment vs. all students who did not express disenchantment, attraction vs. all students who did not express attraction).

Table 8
Regression Models Predicting Biology Course Grade and End-of-Semester Interest in Biology

Predictor	B	*SE*	Beta	Sig.	B	*SE*	Beta	Sig.
Biology course grade								
Intercept	2.75	0.03			2.81	0.02		
Gender	0.07	0.02	0.09	.001	0.07	0.02	0.10	<.001
FG status	−0.12	0.02	−0.16	<.001	−0.05	0.02	−0.07	.004
URM status	−0.18	0.03	−0.17	<.001	−0.11	0.02	−0.11	<.001
BL interest					0.41	0.02	0.57	<.001
BL achievement					0.05	0.02	0.07	.004
BL Interest × Bl Achievement					−0.03	0.02	−0.05	.041
End-of-semester interest								
Intercept	5.50	0.05			5.49	0.04		
Gender	0.01	0.04	0.00	0.889	0.10	0.03	0.01	.712
FG status	−0.03	0.04	−0.03	0.362	−0.05	0.03	−0.04	.119
URM status	0.03	0.05	0.02	0.495	0.02	0.04	0.01	.675
BL interest					0.75	0.03	0.64	<.001
BL achievement					0.02	0.04	0.02	.426
BL Interest × BL Achievement					0.001	0.03	0.00	.974

Note. URM = underrepresented racial/ethnic minority; FG = first-generation; BL = baseline. n = 1,193; missing data addressed using full information maximum likelihood estimation. All models control for whether or not students received interventions and for which of the two studies in this sample students completed; see online supplemental materials for details. Gender: Male = +1, Female = −1. URM status: URM = +1, Majority = −1. FG status: FG = +1; continuing-generation = −1.

who reported both types of reasons for leaving in the "attraction" group for all analyses.[6]

Predicting leaving due to disenchantment. Table 9 presents the results of the multinomial logistic regression analysis. Results for leaving biomedical fields due to feeling disenchantment were very similar to the results for the model predicting attrition overall. When testing only demographic variables as predictors, there was a significant effect of URM status, $b = 0.40$, z = 3.13, $p = .002$, $OR = 1.49$. If students were URM versus majority, they were more likely to report leaving due to disenchantment as compared to remaining in biomedical fields.[7]

In the second model, testing both demographic and psychological predictors, both end-of-semester interest, $b = -0.73$, z = −4.71, $p < .001$, $OR = 0.48$, and biology course grade, $b = -0.74$, z = −4.92, $p < .001$, $OR = 0.48$, negatively predicted students' likelihood of leaving due to disenchantment compared to remaining in biomedical fields. These predictors were equally strong, as seen in Figure 2. Similar to the results for overall attrition, students who received lower grades and students who reported lower levels of interest at the end of the biology course were the most likely to report leaving due to disenchantment compared to remaining in those fields, controlling for baseline interest and prior achievement. There was also a negative interaction effect between students' interest, measured after the biology course, and biology course grades, which was at significance, $b = -0.20$, z = −1.96, $p = .05$, $OR = 0.82$. Interest had a slightly stronger negative effect on feeling disenchantment (vs. remaining in biomedical fields) if students also had higher course grades (see Figure 2).

In the model including psychological predictors, as with overall attrition, FG status became a significant, negative, predictor of reporting leaving due to disenchantment, $b = -0.30$, z = −2.31, $p = .02$, $OR = 0.74$, such that if students were FG versus CG, they were less likely to report leaving due to disenchantment compared to remaining in biomedical fields, after controlling for the psychological variables in the model. The effect of URM status was not significant.

Predicting leaving due to attraction. As can be seen in Table 9, unlike the results for overall attrition and leaving due to disenchantment, no demographic variables predicted the likelihood of leaving due to attraction toward nonbiomedical fields as compared to remaining in biomedical fields. In the second step of the regression, similar to the model predicting overall attrition, students' biology course grades, $b = -0.47$, z = −2.62, $p = .01$, $OR = 0.62$, and end-of-semester interest in biology, $b = -0.73$, z = −4.05, $p < .001$, $OR = 0.48$, both negatively predicted the likelihood of students leaving due to attraction as compared to remaining in biomedical fields. This indicated that students who received lower grades and students who reported lower end-of-semester interest in biology were both more likely to report leaving due to attraction toward nonbiomedical fields, controlling for their baseline interest in biology and prior achievement. Interest was a slightly stronger negative predictor of leaving due to attraction than biology course grades (see Figure 2). Prior achievement also negatively predicted the likelihood of leaving due to attraction, $b = -0.34$, z = −2.05, $p = .04$, $OR = 0.71$, such that students with a history of lower achievement were more likely to report leaving due to attraction compared to remaining in biomedical fields.

[6] If students who articulated both types of reasons for leaving were included with the disenchantment group instead of the attraction group, the significant effects reported here remained significant when predicting students reporting leaving due to disenchantment. When predicting leaving due to attraction, interest remained a significant predictor but biology course grades and the interaction between course grades and interest in biology were no longer significant.

[7] Similar to the results for overall attrition, there was a significant indirect effect of URM status on leaving due to feeling disenchantment, through biology course grades, estimate = 0.10, $SE = 0.03$, z = 3.44, $p = .001$.

Table 9
Likelihood of Leaving for Different Reasons, Compared to Remaining in Biomedical Fields

Predictor	B	*SE*	z	Sig.	*OR*	B	*SE*	z	Sig.	*OR*
Left due to disenchantment										
Intercept	−2.20	0.14				−2.77	0.19			
Gender	−0.09	0.12	−0.73	.465	0.92	−0.04	0.13	−0.35	.721	0.96
FG status	−0.10	0.12	−0.87	.385	0.90	−0.30	0.13	−2.31	.021	0.74
URM status	0.40	0.13	3.13	.002	1.49	0.21	0.14	1.50	.135	1.24
BL achievement						−0.27	0.14	−1.92	.056	0.77
BL interest						0.21	0.14	1.50	.133	1.24
Biology course grade						−0.74	0.15	−4.93	<.001	0.48
EOS interest						−0.73	0.16	−4.71	<.001	0.48
BL Interest × BL Achievement						0.10	0.11	0.86	.387	1.10
EOS Interest × Biology Grade						−0.20	0.10	−1.96	.050	0.82
Left due to attraction										
Intercept	−3.11	0.24				−3.50	0.28			
Gender	−0.23	0.16	−1.48	.140	0.80	−0.24	0.16	−1.46	.144	0.79
FG status	0.03	0.15	0.22	.826	1.03	−0.15	0.16	−0.92	.357	0.86
URM status	−0.10	0.22	−0.46	.648	0.90	−0.25	0.23	−1.05	.292	0.78
BL achievement						−0.34	0.17	−2.05	.041	0.71
BL interest						0.36	0.19	1.88	.060	1.43
Biology course grade						−0.47	0.18	−2.62	.009	0.62
EOS interest						−0.73	0.18	−4.05	<.001	0.48
BL Interest × BL Achievement						−0.03	0.14	−0.22	.827	0.97
EOS Interest × Biology Grade						−0.31	0.14	−2.15	.032	0.74
Vague explanation for leaving										
Intercept	−3.11	0.23				−3.32	0.25			
Gender	−0.13	0.17	−0.76	.446	0.88	−0.05	0.17	−0.29	.774	0.95
FG status	0.06	0.16	0.36	.717	1.06	−0.01	0.17	−0.07	.947	0.99
URM status	0.11	0.20	0.53	.594	1.11	0.00	0.21	0.01	.989	1.00
BL achievement						0.19	0.20	0.93	.353	1.21
BL interest						−0.17	0.18	−0.93	.354	0.85
Biology course grade						−0.61	0.20	−3.09	.002	0.55
EOS interest						−0.07	0.22	−0.31	.758	0.94
BL Interest × BL Achievement						−0.19	0.16	−1.19	.236	0.83
EOS Interest × Biology Grade						0.04	0.13	0.32	.751	1.04

Note. URM = underrepresented racial/ethnic minority; FG = first-generation; *OR* = odds ratio; BL = baseline; EOS = end of semester in which students took introductory biology course. $n = 1193$; missing data addressed using full information maximum likelihood estimation. All models control for whether or not students received interventions and for which of the two studies in this sample students completed; see online supplemental materials for details. Gender: Male = +1, Female = −1. URM status: URM = +1, Majority = −1. FG status: FG = +1; continuing-generation = −1.

Finally, there was a small significant interaction between biology course grade and end-of-semester interest, $b = -0.31$, $z = -2.15$, $p = .03$, $OR = 0.74$. This interaction effect showed that, similar to the effect on leaving due to disenchantment, interest had a stronger negative effect on students leaving due to attraction (vs. remaining in biomedical fields) if students also had higher course performance (see Figure 2).

In summary, the results predicting feeling leaving due to disenchantment were quite similar to those predicting attrition overall, in that lower-achieving students and less-interested students were more likely to report leaving due to disenchantment, compared to remaining in biomedical fields. URM students were also more likely to report leaving due to disenchantment, and this effect was explained in part by these students receiving lower grades in the biology course. The analyses predicting students leaving due to attraction toward nonbiomedical fields revealed a different pattern: Students' interest and biology course grades again both predicted leaving due to attraction, compared to remaining in biomedical fields. However, interest played a slightly larger role than did course grades.

Discussion

The primary aim of this study was to understand whether all students who had started college in biomedical fields of study but left those fields did so because they became disenchanted or whether some students left because they felt attracted to features of nonbiomedical fields. Although all students who leave STEM fields during college likely think about both the negative aspects of their original field of study and positive aspects of a new field of study when deciding on their major or career path, results of the present study demonstrate that there is substantial variability in whether students predominantly reflected on their attrition in terms of reasons related to attraction versus disenchantment. Indeed, a large proportion of the students who left biomedical fields (37.4%) explained their attrition in terms of at least some positive features that attracted them toward a nonbiomedical field of study, and one quarter of students explained their attrition exclusively in terms of attraction factors. These results highlight the importance of considering not just the factors that may cause students to perceive STEM fields negatively, but also factors that might make students

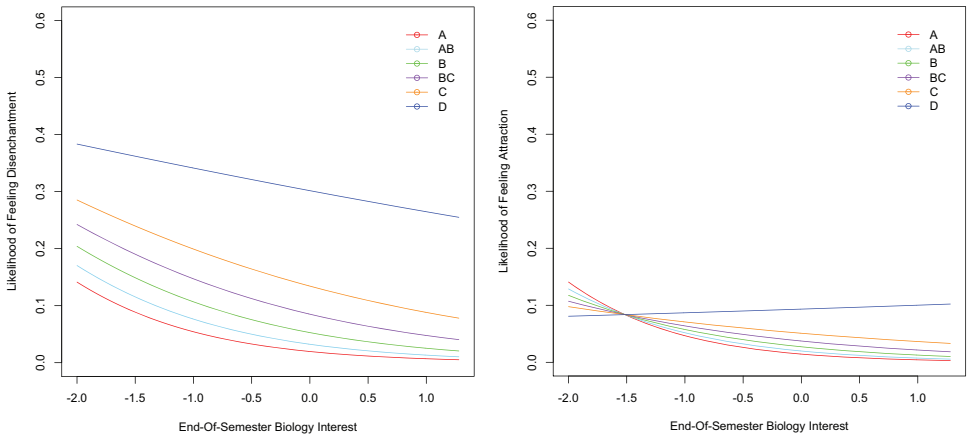

Figure 2. Relation between interest in biology at the end of the introductory course (standardized, plotted up to the maximum value of 1.28) and types of attrition from biomedical fields (disenchantment in left panel; attraction in right panel), estimated at different course grades (grade distribution across students is as follows: A, $n = 167$; AB, $n = 120$; B, $n = 534$; BC, $n = 109$; C, $n = 218$; D, $n = 42$; *F*, $n = 3$). See the online article for the color version of this figure.

perceive other fields of study positively, in order to obtain a more nuanced understanding of STEM attrition. Such findings are consistent with a growing body of research (e.g., Diekman et al., 2010; Eccles, 2009; Gaspard, Wille, Wormington, & Hulleman, 2019; Ost, 2010) suggesting that students consider aspects of both STEM and non-STEM majors and careers when deciding to leave STEM fields of study. They also provide evidence for the kinds of attraction-disenchantment tensions discussed in prior research (Seymour & Hewitt, 1997; Thoman et al., 2014). These results extend prior work in examining the relative importance that students place on attraction versus disenchantment in explaining their attrition decisions, and in examining the factors that predict distinct types of attrition.

It is important to understand the experiences of students who report leaving due to feeling attraction versus disenchantment, in order to provide different students with appropriate educational supports. Results of the interviews offer suggestions for how to develop such supports. Students who expressed leaving due to attraction almost all described perceiving high interest in or value for nonbiomedical majors and career paths, with most students referencing interest or fit. This occurred despite most students having clear initial plans to pursue biomedical careers, suggesting that students can be drawn toward positive aspects of alternative fields even if they thought they were initially committed to a certain career. Students' emphasis on interest and enjoyment of nonbiomedical fields, or fit with those fields, suggest that intrinsic and attainment components of students' task values may be key determinants of them leaving due to other fields' attraction. If educators want to retain these students in biomedical fields, they need to focus on more than reducing barriers to success within biomedical fields. Rather, they need to make a positive case for the biomedical fields by emphasizing the interesting features of these fields, or by doing more to support students' sense of identification with them. One option may be to try and support students' academic values across different domains simultaneously, by emphasizing interdisciplinary topics that include biomedical material, or by encouraging students to pursue biomedical fields of study alongside other fields (e.g., through a double major, or a career that utilizes biomedical competencies but lies within a nonbiomedical field). Given the importance of STEM skills for both STEM and non-STEM careers (National Science Board, 2018), such efforts could ensure that interested students continue to develop important STEM competencies without asking them to give up on other options with which they identify. A third possibility for educators is to accept these students' decisions as they move on to other fields, and focus retention efforts on other students.

The responses from the students who left primarily due to attraction also shed light on how to attract undecided or nonbiomedical students into biomedical majors or careers. In particular, students who left due to attraction expressed enthusiasm for and interest in features of nonbiomedical coursework or careers. This contrasts sharply with the descriptions of biomedical fields given by the students who left due to disenchantment with biomedical fields, and with the descriptions often made in extant literature of introductory lecture-based STEM courses as dense, boring, and tedious (also see Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; President's Council of Advisors on Science and Technology, 2012; Seymour & Hewitt, 1997). If educators strive to make introductory biomedical coursework more stimulating and engaging, they might evoke greater enthusiasm from undecided or nonbiomedical students and possibly draw them from other fields and toward biomedical fields.

When students expressed leaving biomedical fields primarily due to feelings of disenchantment, about half discussed factors that made them lose interest in their original major or career path or perceive that it was not valuable to them (e.g., they found coursework to be boring; they would not enjoy the day-to-day tasks associated with a particular career). Another 30% of students referenced low confidence or perceived ability as the primary factor influencing their decisions (e.g., they could not get into medical school). These students did not report perceiving positive aspects of their new field of study. Educators can best support these students by trying to address the factors that make students perceive their STEM coursework as boring and difficult, in order

to help prevent them from leaving biomedical fields without any strong desire to pursue an alternative field. It also may be useful to help students perceive difficulty in courses as a worthwhile positive challenge, which may help them frame their negative experiences in a more positive light and thus feel less demoralized after having such experiences. Finally, preemptive measures that ensure students are informed about the types of coursework they will pursue en route to a given major, or the day-to-day tasks associated with certain careers, may help prevent students from engaging with fields of study that ultimately lead to disappointment.

Predicting Attrition, Feelings of Disenchantment, and Feelings of Attraction

Another goal of this study was to explore what factors predicted whether students left biomedical fields primarily due to disenchantment or attraction. Although much prior research has examined the factors that predict attrition from STEM fields, research has not distinguished between different types of attrition, nor examined whether different factors predict the two types.

Our overall attrition results were generally consistent with prior research (e.g., Chen, 2013; Eccles, 2009; Perez et al., 2014, 2019). Controlling for baseline interest and prior achievement, students who earned lower grades in an introductory biology course and students with lower interest in biology at the end of the course were significantly more likely to leave biomedical fields compared to remaining in those fields. Also consistent with prior research, we found that URM students were significantly more likely to leave biomedical fields than were majority students (Beasley & Fischer, 2012; Chang et al., 2014; National Science Board, 2018; Shaw & Barbuti, 2010). Process analyses suggested that these students' higher attrition was associated in part with their having received lower biology course grades. Results highlight the critical importance of addressing racial and ethnic achievement gaps in STEM courses as a route to reduce STEM attrition. Educators can try to address this goal by helping to ensure that URM students receive appropriate educational supports to help them succeed in introductory college STEM courses. Interventions that aim to promote interest, perceptions of belonging, or course performance for underrepresented students may be particularly helpful in this regard (e.g., Brown, Smith, Thoman, Allen, & Muragishi, 2015; Cohen, Garcia, Apfel, & Master, 2006; Harackiewicz, Smith, & Priniski, 2016; Walton & Cohen, 2007, 2011).

Results were inconsistent with prior research in that FG status did not predict attrition in models using only demographic predictors; in fact, FG students were less likely to leave due to feelings of disenchantment in models that included psychological predictors. This finding suggests that FG students were particularly motivated to remain in biomedical fields for reasons beyond their achievement and interest in biology. It is possible that FG students' major and career decisions are impacted by a unique set of factors that were not captured in the current study (Stephens, Markus, & Phillips, 2014). We encourage researchers to test whether this finding replicates in other contexts and to study the dynamics of attrition for FG students across different STEM fields in future research.

With respect to distinct types of attrition, we found that many of the same factors predicting overall attrition also predicted students leaving biomedical fields due to disenchantment compared to remaining in those fields (biology course grades, interest in biology at the end of the semester, and URM status). These results are consistent with the interview responses suggesting that low interest in biomedical subjects and low perceptions of competence in biomedical courses were two key factors that made students want to leave biomedical fields. These findings underscore the conclusions drawn above: As a path to prevent students from perceiving STEM fields negatively, educators should try to help them succeed during challenging introductory courses (particularly URM students who may receive lower grades), in addition to trying to emphasize the interesting features of STEM fields of study for students' lives.

Results predicting students' leaving due to attraction to other fields were quite different. Reporting lower interest at the end of the introductory biology course and having lower course grades were both associated with leaving due to attraction (as compared to remaining in biomedical fields), controlling for baseline interest and prior achievement. However, end-of-semester interest was a somewhat stronger predictor relative to course grades. It appears that students who felt attracted to nonbiomedical fields were not as heavily influenced by biology course grades as were students who felt disenchantment with biomedical fields. Given that these two groups did not have significantly different course performance, it may be that students who respond more poorly to low biology course grades become more likely to think about their attrition in disenchantment-related terms. The relatively higher frequency of "disenchantment" students referencing competence and ability in the interviews supports this supposition, as it suggests that low grades were more salient to this group. It is not the case that students who left due to attraction were unaffected by their biology course grades, but these students seem to have been somewhat more strongly affected by factors related to interest, both in terms of declining interest in biomedicine and increasing interest in another field.

Interest in biology was the strongest predictor of students leaving due to attraction in the regression models; this contrasts the interview responses of students in this group, who did not often reference declining interest in biology and instead often referenced a growing interest in other fields as the primary determinant of their plans changing. Even in the "both attraction and disenchantment" group, which provides the clearest information about students' decision-making processes with respect to both old and new majors, less than half of students stated that loss of interest in biomedical fields caused them to notice or seek out more positive experiences in other fields. These findings suggest that perceiving low interest in biology relative to one's peers may make students more susceptible to being attracted toward alternative fields, but students might not realize that low interest played a salient a role in their decisions. Research grounded in expectancy-value theory reports that high school students perceive values in a hierarchy across subjects; if students perceive strong value for one subject they may come to devalue subjects or fields that are not closely related to it (Eccles, 2009; Gaspard et al., 2018; Guo, Marsh, Parker, Morin, & Dicke, 2017; Lauermann, Chow, & Eccles, 2015). In the present study, it may be the case that some students who began to perceive low interest in biomedical fields were more likely to perceive higher interest in other fields over time, without necessarily being aware of this shift. Together, these findings suggest that it if students experience both low interest in biology

and positive interest or fit experiences in other fields, they are particularly likely to feel attracted toward nonbiomedical fields.

We also found an interaction suggesting that the effects of end-of-semester biology interest on leaving due to attraction (vs. remaining in biomedical fields) were strongest for the highest-achieving students, controlling for baseline interest and prior achievement. It is not surprising that low interest may be more impactful when students have higher course performance. Higher-performing students may feel capable of making decisions based on comparing their interests across different fields, because they were relatively successful in the introductory biology course and might assume they are capable of succeeding in alternative majors as well. In contrast, lower-performing students may be very concerned about finding a field in which they can perform well, and thus they might give their interests less weight in deciding whether or not to change fields of study.

Broadly, both the qualitative and quantitative findings point to the critical importance of interest in shaping students' decisions about leaving biomedical fields for any reason (Harackiewicz et al., 2016; Renninger & Hidi, 2016). In this study, most students entered the biology course with interest in pursuing a biomedical career, but their interest at the end of the course proved to be at least as strong a predictor as course performance of both types of attrition. High levels of end-of-semester interest were associated with remaining in the field, whereas lower levels of end-of-semester interest were associated with leaving the field. Much attention is given to the role of poor performance in introductory courses in predicting attrition (e.g., Chen, 2013), as we have already discussed, but it is critical to consider the equal importance of interest in shaping students' attrition decisions. If educators want to ensure that students continue to take STEM courses into the future and perceive their STEM fields of study positively, it is important that they ensure that their course material is stimulating and that students perceive the value of what they are studying. Otherwise, they risk losing students who come into a course with high initial interest choosing to opt out of these fields over time.

Conclusions and Future Directions

We recommend that researchers build upon the findings of the present study by examining attraction- and disenchantment-related reasons for leaving in a broader variety of STEM subjects and with different populations of STEM college students. We believe that the findings presented here are generalizable to other STEM subjects, but there may be additional factors to consider in other STEM disciplines. For example, there may be gender differences in reasons for attrition from STEM fields such as physics and engineering, in which women are seriously underrepresented among students, faculty, and in the workforce (National Science Foundation, 2017). Such fields can be characterized by a lack of role models and a lower sense of belonging for women (Walton, Logel, Peach, Spencer, & Zanna, 2015); as well as more experiences of gender bias from both peers and professors (Robnett, 2016). In terms of non-STEM subject areas, we do not assume that the results presented here would generalize to other types of major changes (e.g., changing from a business major to a humanities major). Although individuals likely would consider attraction and disenchantment reasons for leaving in all subject areas, the prevalence of these different reasons for attrition and the factors predicting these types of attrition would likely differ across subject areas. Similarly, the present study treated all students who remained in a biomedical major or career similarly. There is much variability in students' career pursuits within these fields, and that could provide additional insight regarding how students change their career plans throughout the course of college.

Another limitation is that we collected data regarding some, but not all, psychological predictors of attrition. Future researchers should explore the role of more psychological predictors in predicting distinct types of attrition to understand this topic further. In particular, this study used course grades and prior achievement as predictors, while expectancy-value theory would suggest that students' competence-related beliefs (and not their actual competence) are more proximal predictors of their motivated academic behavior. We believe that grades serve as a useful indicator of competence-related beliefs, but future research should explore in more depth whether these beliefs predict types of attrition in any ways distinct from grades.

This study explored one dimension of students' reasons for attrition from STEM fields, that of disenchantment versus attraction. Although we believe that this dimension is one of the most critical for understanding why and how students leave STEM fields, there also may be other important dimensions of STEM major choices that can be informative, such as whether students felt that internal factors shaped their decision-making (e.g., low confidence) or whether external interactions or experiences were more influential (e.g., conversations with an advisor).

A final limitation of the present study is that we did not have a sufficient sample size to address questions related to intersectionality among the demographic variables. Students' intersecting gender, social class, and racial or ethnic identities shape their experiences in college STEM courses in ways that cannot be understood only by examining one demographic factor at a time (e.g., Else-Quest & Hyde, 2016; Harackiewicz et al., 2016). We recommend that researchers build upon the results reported here by examining students' intersecting identities as they relate to their decisions to remain in or leave STEM majors.

Broadly, we designed the present study to shed light on the attraction- and disenchantment-related dynamics that may cause students to leave STEM fields. These results may help educators understand the reasons why different students leave STEM fields, which may ultimately help provide more effective and equitable education.

References

Association of American Colleges and Universities. (2013). It takes more than a major: Employer priorities for college learning and student success. *Liberal Education*. Retrieved from https://www.aacu.org/sites/default/files/files/LEAP/2013_EmployerSurvey.pdf

Bakeman, R., & Quera, V. (2011). *Sequential analysis and observational methods for the behavioral sciences*. New York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9781139017343

Beasley, M. A., & Fischer, M. J. (2012). Why they leave: The impact of stereotype threat on the attrition of women and minorities from science, math and engineering majors. *Social Psychology of Education: An International Journal, 15,* 427–448. http://dx.doi.org/10.1007/s11218-012-9185-3

Brown, E. R., Smith, J. L., Thoman, D. B., Allen, J. M., & Muragishi, G. (2015). From Bench to Bedside: A communal utility value intervention

to enhance students' biomedical science motivation. *Journal of Educational Psychology, 107,* 1116–1135. http://dx.doi.org/10.1037/edu0000033

Chang, M. J., Sharkness, J., Hurtado, S., & Newman, C. B. (2014). What matters in college for retaining aspiring scientists and engineers from underrepresented racial groups. *Journal of Research in Science Teaching, 51,* 555–580. http://dx.doi.org/10.1002/tea.21146

Chen, X. (2013). *STEM attrition: College students' paths into and out of STEM fields* (Report No. 2014–001). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Retrieved from http://nces.ed.gov/pubs2014/2014001rev.pdf

Cheryan, S., Ziegler, S. A., Montoya, A. K., & Jiang, L. (2017). Why are some STEM fields more gender balanced than others? *Psychological Bulletin, 143,* 1–35. http://dx.doi.org/10.1037/bul0000052

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20,* 37–46.

Cohen, G. L., & Garcia, J. (2008). Identity, belonging, and achievement: A model, interventions, implications. *Current Directions in Psychological Science, 17,* 365–369. http://dx.doi.org/10.1111/j.1467-8721.2008.00607.x

Cohen, G. L., Garcia, J., Apfel, N., & Master, A. (2006). Reducing the racial achievement gap: A social-psychological intervention. *Science, 313,* 1307–1310. http://dx.doi.org/10.1126/science.1128317

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science, 21,* 1051–1057. http://dx.doi.org/10.1177/0956797610377342

Dika, S. L., & D'Amico, M. M. (2016). Early experiences and integration in the persistence of first-generation college students in STEM and non-STEM majors. *Journal of Research in Science Teaching, 53,* 368–383. http://dx.doi.org/10.1002/tea.21301

Eccles, J. S. (2007). Where are all the women? Gender differences in participation in physical science and engineering. In S. J. Ceci & W. M. Williams (Eds.), *Why aren't more women in science? Top researchers debate the evidence* (pp. 199–210). Washington, DC: American Psychological Association.

Eccles, J. (2009). Who am I and what am I going to do with my life? Personal and collective identities as motivators of action. *Educational Psychologist, 44,* 78–89. http://dx.doi.org/10.1080/00461520902832368

Eccles, J. S. (2013). Keynote-gender and STEM: Opting in versus dropping out. *International Journal of Gender, Science and Technology, 5,* 184–186.

Eccles-Parsons, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motivation* (pp. 75–146). San Francisco, CA: Freeman.

Else-Quest, N. M., & Hyde, J. S. (2016). Intersectionality in quantitative psychological research: I. Theoretical and epistemological issues. *Psychology of Women Quarterly, 40,* 155–170. http://dx.doi.org/10.1177/0361684316629797

Finkelstein, S., Hambrick, D., & Cannella, A. A. (1996). *Strategic leadership*. St. Paul, MN: West Educational Publishing.

Gasiewski, J. A., Eagan, M. K., Garcia, G. A., Hurtado, S., & Chang, M. J. (2012). From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Research in Higher Education, 53,* 229–261. http://dx.doi.org/10.1007/s11162-011-9247-y

Gaspard, H., Wigfield, A., Jiang, Y., Nagengast, B., Trautwein, U., & Marsh, H. W. (2018). Dimensional comparisons: How academic track students' achievements are related to their expectancy and value beliefs across multiple domains. *Contemporary Educational Psychology, 52,* 1–14. http://dx.doi.org/10.1016/j.cedpsych.2017.10.003

Gaspard, H., Wille, E., Wormington, S. V., & Hulleman, C. S. (2019). How are upper secondary school students' expectancy-value profiles associated with achievement and university STEM major? A cross-domain comparison. *Contemporary Educational Psychology, 58,* 149–162. http://dx.doi.org/10.1016/j.cedpsych.2019.02.005

Guo, J., Marsh, H. W., Parker, P. D., Morin, A. J., & Dicke, T. (2017). Extending expectancy-value theory predictions of achievement and aspirations in science: Dimensional comparison processes and expectancy-by-value interactions. *Learning and Instruction, 49,* 81–91. http://dx.doi.org/10.1016/j.learninstruc.2016.12.007

Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Giffen, C. J., Blair, S. S., Rouse, D. I., & Hyde, J. S. (2014). Closing the social class achievement gap for first-generation students in undergraduate biology. *Journal of Educational Psychology, 106,* 375–389. http://dx.doi.org/10.1037/a0034679

Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Priniski, S. J., & Hyde, J. S. (2016). Closing achievement gaps with a utility-value intervention: Disentangling race and social class. *Journal of Personality and Social Psychology, 111,* 745–765. http://dx.doi.org/10.1037/pspp0000075

Harackiewicz, J. M., Durik, A. M., Barron, K. E., Linnenbrink-Garcia, L., & Tauer, J. M. (2008). The role of achievement goals in the development of interest: Reciprocal relations between achievement goals, interest, and performance. *Journal of Educational Psychology, 100,* 105–122. http://dx.doi.org/10.1037/0022-0663.100.1.105

Harackiewicz, J. M., & Priniski, S. J. (2018). Improving student outcomes in higher education: The science of targeted intervention. *Annual Review of Psychology, 69,* 409–435. http://dx.doi.org/10.1146/annurev-psych-122216-011725

Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest matters: The importance of promoting interest in education. *Policy Insights from the Behavioral and Brain Sciences, 3,* 220–227. http://dx.doi.org/10.1177/2372732216655542

Hecht, C. A., Harackiewicz, J. M., Priniski, S. J., Canning, E. A., Tibbetts, Y., & Hyde, J. S. (2019). Promoting persistence in the biological and medical sciences: An expectancy-value approach to intervention. *Journal of Educational Psychology, 11,* 1462–1477. http://dx.doi.org/10.1037/edu0000356

Heilbronner, N. N. (2011). Stepping onto the STEM pathway: Factors affecting talented students' declaration of STEM majors in college. *Journal for the Education of the Gifted, 34,* 876–899. http://dx.doi.org/10.1177/0162353211425100

King, B. (2015). Changing college majors: Does it happen more in STEM and do grades matter? *Journal of College Science Teaching, 44,* 44–51. http://dx.doi.org/10.2505/4/jcst15_044_03_44

Lauermann, F., Chow, A., & Eccles, J. S. (2015). Differential effects of adolescents' expectancy and value beliefs about math and English on math/science-related and human services-related career plans. *International Journal of Gender, Science and Technology, 7,* 205–228.

Lent, R. W., Brown, S. D., Schmidt, J., Brenner, B., Lyons, H., & Treistman, D. (2003). Relation of contextual supports and barriers to choice behavior in engineering majors: Test of alternative social cognitive models. *Journal of Counseling Psychology, 50,* 458–465. http://dx.doi.org/10.1037/0022-0167.50.4.458

Lent, R. W., Sheu, H. B., Singley, D., Schmidt, J. A., Schmidt, L. C., & Gloster, C. S. (2008). Longitudinal relations of self-efficacy to outcome expectations, interests, and major choice goals in engineering students. *Journal of Vocational Behavior, 73,* 328–335. http://dx.doi.org/10.1016/j.jvb.2008.07.005

Maltese, A. V., Melki, C. S., & Wiebke, H. L. (2014). The nature of experiences responsible for the generation and maintenance of interest in STEM. *Science Education, 98,* 937–962. http://dx.doi.org/10.1002/sce.21132

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education, 95,* 877–907. http://dx.doi.org/10.1002/sce.20441

Nagengast, B., Marsh, H. W., Scalas, L. F., Xu, M. K., Hau, K.-T., & Trautwein, U. (2011). Who took the "×" out of expectancy-value theory? A psychological mystery, a substantive-methodological synergy, and a cross-national generalization. *Psychological Science, 22,* 1058–1066. http://dx.doi.org/10.1177/0956797611415540

National Institutes of Health. (2015). NIH-wide strategic plan, fiscal years 2016-2020: Turning discovery into health. Retrieved from https://www.nih.gov/sites/default/files/about-nih/strategic-plan-fy2016-2020-508.pdf

National Science Board. (2018). *Science and engineering indicators 2018*. Retrieved from nsf.gov

National Science Foundation. (2017). *Women, minorities, and persons with disabilities in science and engineering*. Retrieved from www.nsf.gov/statistics/2015/nsf15311/tables.cfm

Ost, B. (2010). The role of peers and grades in determining major persistence in the sciences. *Economics of Education Review, 29,* 923–934. http://dx.doi.org/10.1016/j.econedurev.2010.06.011

Ostrove, J. M., & Long, S. M. (2007). Social class and belonging: Implications for college adjustment. *The Review of Higher Education: Journal of the Association for the Study of Higher Education, 30,* 363–389. http://dx.doi.org/10.1353/rhe.2007.0028

Perez, T., Cromley, J. G., & Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. *Journal of Educational Psychology, 106,* 315–329. http://dx.doi.org/10.1037/a0034027

Perez, T., Dai, T., Kaplan, A., Cromley, J. G., Brooks, W. D., White, A. C., . . . Balsai, M. J. (2019). Interrelations among expectancies, task values, and perceived costs in undergraduate biology achievement. *Learning and Individual Differences, 72,* 26–38. http://dx.doi.org/10.1016/j.lindif.2019.04.001

President's Council of Advisors on Science and Technology. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. A Report by the President's Council of Advisors on Science and Technology. Washington, DC: Author.

Renninger, K. A., & Hidi, S. (2016). *The power of interest for motivation and engagement*. New York, NY: Routledge.

Renninger, K. A., Neilsen, S., & Nam, M. (2017, August). *What makes the difference for highly selective undergraduates who continue to pursue STEM?* Paper presented at the Interest, Motivation and Aspirations in STEM: How Do These Factors Develop and Influence Each Other? Symposium, Tampere, Finland.

Robnett, R. D. (2016). Gender bias in STEM fields: Variation in prevalence and links to STEM self-concept. *Psychology of Women Quarterly, 40,* 65–79. http://dx.doi.org/10.1177/0361684315596162

Seymour, E., & Hewitt, N. M. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press.

Shaw, E. J., & Barbuti, S. (2010). Patterns of persistence in intended college major with a focus on STEM majors. *NACADA Journal, 30,* 19–34. http://dx.doi.org/10.12930/0271-9517-30.2.19

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69,* 797–811. http://dx.doi.org/10.1037/0022-3514.69.5.797

Steele, C. M., Spencer, S. J., & Aronson, J. (2002). Contending with group image: The psychology of stereotype and social identity threat. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 34, pp. 379–440). San Diego, CA: Academic Press. http://dx.doi.org/10.1016/S0065-2601(02)80009-0

Stephens, N. M., Markus, H. R., & Phillips, L. T. (2014). Social class culture cycles: How three gateway contexts shape selves and fuel inequality. *Annual Review of Psychology, 65,* 611–634. http://dx.doi.org/10.1146/annurev-psych-010213-115143

Strenta, A. C., Elliott, R., Adair, R., Matier, M., & Scott, J. (1994). Choosing and leaving science in highly selective institutions. *Research in Higher Education, 35,* 513–547. http://dx.doi.org/10.1007/BF02497086

Thoman, D. B., Arizaga, J. A., Smith, J. L., Story, T. S., & Soncuya, G. A. (2014). The grass is greener in non-STEM: Examining the role of competing belonging in undergraduate women's vulnerability to being pulled away from science. *Psychology of Women Quarterly, 38,* 246–258. http://dx.doi.org/10.1177/0361684313499899

Tibbetts, Y., Harackiewicz, J. M., Canning, E. A., Boston, J. S., Priniski, S. J., & Hyde, J. S. (2016). Affirming independence: Exploring mechanisms underlying a values affirmation intervention for first-generation students. *Journal of Personality and Social Psychology, 110,* 635–659. http://dx.doi.org/10.1037/pspa0000049

Walton, G. M., & Cohen, G. L. (2007). A question of belonging: Race, social fit, and achievement. *Journal of Personality and Social Psychology, 92,* 82–96. http://dx.doi.org/10.1037/0022-3514.92.1.82

Walton, G. M., & Cohen, G. L. (2011). A brief social-belonging intervention improves academic and health outcomes of minority students. *Science, 331,* 1447–1451. http://dx.doi.org/10.1126/science.1198364

Walton, G. M., Logel, C., Peach, J. M., Spencer, S. J., & Zanna, M. P. (2015). Two brief interventions to mitigate a "chilly climate" transform women's experience, relationships, and achievement in engineering. *Journal of Educational Psychology, 107,* 468–485. http://dx.doi.org/10.1037/a0037461

Walton, G. M., & Wilson, T. D. (2018). Wise interventions: Psychological remedies for social and personal problems. *Psychological Review, 125,* 617–655. http://dx.doi.org/10.1037/rev0000115

Wang, M. T., & Degol, J. (2014). Staying engaged: Knowledge and research needs in student engagement. *Child Development Perspectives, 8,* 137–143. http://dx.doi.org/10.1111/cdep.12073

Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review, 29,* 119–140. http://dx.doi.org/10.1007/s10648-015-9355-x

Wang, M. T., Eccles, J. S., & Kenny, S. (2013). Not lack of ability but more choice: Individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychological Science, 24,* 770–775. http://dx.doi.org/10.1177/0956797612458937

Wigfield, A., Rosenzweig, E. Q., & Eccles, J. (2017). Competence values. In A. Elliot, C. Dweck, & D. Yeager (Eds.), *Handbook of competence and motivation: Theory and application* (2nd ed., pp. 116–134). New York, NY: Guilford Press.

Wigfield, A., Tonks, S. M., & Klauda, S. L. (2016). Expectancy-value theory. In K. R. Wentzel & D. B. Miele (Eds.), *Handbook of motivation of school* (2nd ed., pp. 55–74). New York, NY: Routledge.

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